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Reliability Study of the Hitachi H34C Accelerometer in Wireless Body Area Networks for Fall Detection

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Abstract - **A WBAN (Wireless Body Area Network) allows connecting several sensor nodes into one sensor network. Each sensor node can be provided with a dedicated sensor. In case of fall detection, the physical movements of the body, which show characteristic patterns typical for a falling body, are used to generate a warning signal. Physical movements of the body can be measured by accelerometers. Today there is a lot of progress in the area of MEMS accelerometers. They are very small and hence can get integrated in WBAN sensor nodes. This paper proposes a setup and evaluation of a WBAN with multiple accelerometer nodes for an application in fall detection.**
Keywords **– WBAN, accelerometer, fall detection**

I. INTRODUCTION

During the last twenty years, the number of persons above 65 years has grown extensively. Prospections on the future predict that this number will still continue to grow while the persons below 50 years will remain status quo. Elderly people require more aid than younger persons. This aging of the population is putting a lot of stress on our health care. A fall incident from a person above 50 years can cause serious injuries, such as hip fracture, head traumas and increases the morbidity.

One out of three persons above 65 years old experiences at least one fall incident per year [1]. A serious side-effect of a fall incident is the so-called 'long-lie', where the person remains immobile after a fall and does not succeed in getting up [2].

The injuries caused from a fall incident can be severely reduced by the quick response of other people or care givers. Therefore there is a need for an alarm system, which signals the next-of-kin or care-givers. This response of the alarm system is greatly dependent on the reliability and accuracy of the sensors. These sensors are incorporated in the alarm system and detect the fall incident, triggering the alarm.

In this study we present a proof-of-concept system that consists of a wireless sensor network, composed of several nodes. Each node contains a programmable logic, a wireless transceiver and sensors.

Nowadays, a single sensor is used for the detection of a fall incident. In our study we want to demonstrate the possibility of incorporating multiple sensor information placed on different parts of body to detect a fall incident. In Section II we present the Eco platform, introduce the 3-axial accelerometer, explain the measurement setup and make a distinction between static and dynamic measurement methods. Section III describes the measurement results, the translation of the data into g-values and presents the example case of a falling body. Finally an overview about future work is discussed.

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II. MATERIALS AND METHODS

A. Wireless body area network system

The wireless body area network makes use of the Eco platform, developed at the Center for Embedded computing Systems University of California. It is a self-contained, ultra-wearable and expandable wireless sensor platform under 1cm³ [4]. The WBAN consists of several Eco Sensor nodes (Figure 1).

Figure 1 shows the Eco Senor node's main component description. Each Eco sensor node consists of four subsystems: MCU/Radio, Sensors, Power, and expansion port. In this experiment we use the 3-axial accelerometer as sensing device.

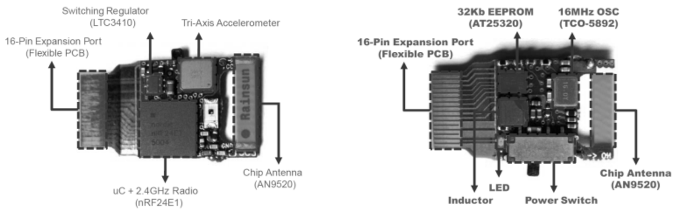


FIGURE 1. ECO NODE

B. Eco platform

The Eco platform consists of the Eco sensor node, the Data Aggregator, and the Development/Base-Station Board.

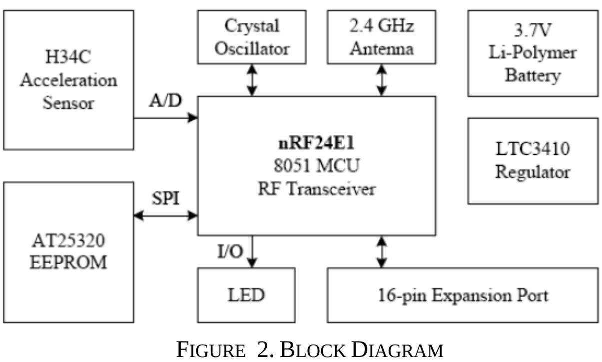


FIGURE 2. BLOCK DIAGRAM

Eco uses Nordic VLSI's nRF24E1, a 2.4 GHz RF transceiver with an embedded 8051-compatible MCU (DW8051). The nRF24E1's 2.4GHz transceiver uses a GFSK modulation scheme with 125 frequency channels that are 1MHz apart. The maximum RF output power is 0dBm at the maximum data rate of 1Mbps. The nRF24E1 also provides a 10-bit 9 input 100 kSPS AD converter. [4] Figure 2 shows the block diagram [3].

C. The Accelerometer

A 3-axial accelerometer is used to measure the mechanical movement of a body in 3 directions XYZ (Figure 3) which corresponds to a reference frame as in a 3-dimensional Euclidean space. With the accelerometer we measure the acceleration of a human body.

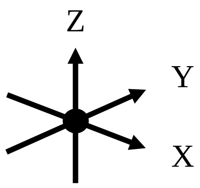


FIGURE 3 THREE AXES X Y Z

Eco has a 3-axial acceleration sensor, Hitachi Metals H34C (3.4mm × 3.7mm × 0.92mm). It measures accelerations form -3g to +3g and temperatures from 0 to 75°C while consuming 0.36mA at 3V in active mode [3].

The output values for acceleration from the sensor node are in the range [1000-4000]. As most systems express the accelerometer values in g-values, we want to translate the data captured from the accelerometer into g-values. Due to gravitation the accelerometer always encounters 1g. As illustrated in Figure 3 the Z axis is vertical and will encounter a 1 g gravitational force. This means that the measured accelerometer values at the axes X and Y should correspond with 0 g.

D. The Measurement Setup

First we have to determine the three principal axes X, Y and Z in relation to the physical construction of the accelerometer housing. The measured accelerometer data of the Eco sensor-node is captured by its microcontroller. By means of a data frame, that contains an ID-number and the accelerometer XYZ-values, the data is wireless transmitted to the receiver. The structure of the data frame of the incoming data is shown in Figure 4. The frame consists of a node ID, the identification number of the sensor node, followed by the 4 digit XYZ-values.

ID	X				Y				Z			

FIGURE 4. DATA FRAME

The client side Eco sends a data frame with acceleration data to the base side Eco every 20ms. In its turn the base side Eco will transfer the data to the host side via UART [3]. A PC application then stores this data as datasets in text files. These datasets will be further exploited in Scilab. Scilab is an open source numerical computational package which is quite similar to Matlab.

As the sensor node is quite small, a mechanical housing to hold the sensor node has been created. The mechanical structure has been drawn with SketchUp a 3D CAD program and printed in PLA plastic with an Ultimate 3D printer (Figure 5).

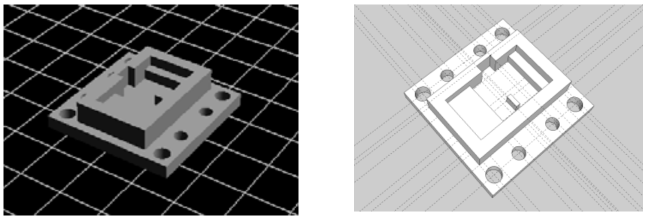


FIGURE 5. 3D DRAWING HOLDER ECO NODE

The sensor node fits inside the plastic housing of the Eco node holder (Figure 6).

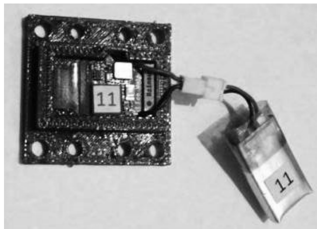


FIG. 6. ECO NODE IN PLASTIC HOLDER

A static and dynamic measurement method has been applied.

E. Static method

The sensor node inside the holder (Figure 6) was put in 6 positions to obtain the accelerometer maximum and minimum values for each of the 3 directions XYZ (Figure 3). The measured values are displayed in Table 1.

F. Dynamic method

To learn more about the dynamic behavior of the accelerometer, the sensor node was mounted on a vibration table (Figure 7). By means of a function generator a sinusoidal signal was applied to the control unit of the vibration table to produce a sinusoidal mechanical movement.

Vibration Table

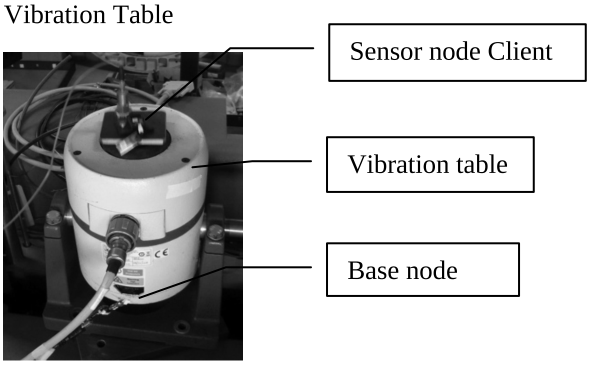


FIGURE 7. VIBRATION TABLE

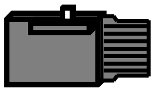
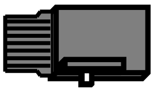
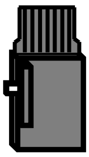
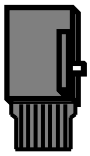
The datasets were captured while the table was vibrating at a sinusoidal frequency in the range of 3 Hz upto 15 Hz. The measurements have been repeated for the 3 directions X, Y and Z.

III. RESULTS

A. Static method

When the sensor is at rest, its average value obtained from is dependent on the orientation with respect to the gravitation. The sensor was held in 6 static positions, in each position one is always perpendicular to the earth surface. The pictures in Table 1 show the position of the sensor node for each direction in relation to the earth surface. For instance, for the upper picture, the switch is positioned on top.

TABLE 1. REFERENCE VALUES

Position	Value =>	X	Y	Z
X		2115	2630	2620
		3340	2630	2625
Y		2650	2155	2615
		2645	3355	2635
Z		2640	2615	3335
		2640	2625	2155

Now we needed to translate the measured values to vector values. When evaluating the values in Table 1 we can distinguish by estimation 3 major values: 3340, 2640 and 2140. These values were characteristic for the accelerometer for the case of -1g, 0g and +1g. By using this data we calculated the value which corresponds to 1g.
3340 – 2640 = 700
2640 – 2140 = 500
We expected to see twice the same value.
This measurement method doesn't seem to be very accurate.

Literature mentions more sophisticated evaluation methods to obtain the 0g reference point. One such alternative solution is the method for auto calibration of MEMS Accelerometers [5]. This gives us the result for X_0g = 2732, Y_0g = 2742 and Z_0g = 2759.

B. Dynamic method

The sensor node was mounted on a vibration table (Figure 7). We noticed a distortion of the signals at low frequencies (Figure 8). One of the drawbacks of performing measurements at low frequencies is the distortion of the measurement signals.

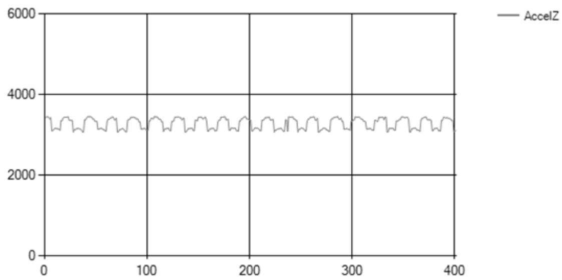


FIGURE 8. SINUSOIDAL MOVEMENT FOR Z-AXIS

By using our datasets we made an estimation of the 3 reference values.
We obtained 3300, 2650 and 2000 for the case of -1g, 0g and +1g. Now we calculated the value which corresponds with 1g.
3300 – 2650 = 650
2650 – 2000 = 650

For further exploration of our fall detection system we used these values to calculate the vector values x, y, z and the resultant r.
x = (x_value-2650)/650
y = (y_value-2650)/650
z = (z_value-2650)/650

$r^2 = x^2 + y^2 + z^2$

C. PC Software

A C# PC application was created to capture the data of the sensor nodes via USB-serial communication, storing it as datasets in files. The rough data from the 3 axes X, Y, Z is visualized in separate graphs (Figure 9).

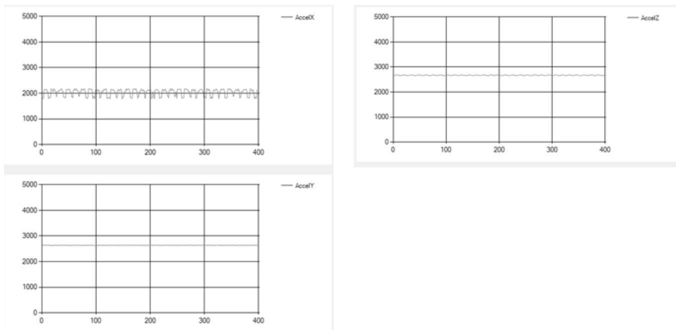


FIGURE 9. ECO NODE SENSOR DATA

The PC application also converted the rough accelerometer XYZ data into the corresponding better understandable g-values. (Figure 12 and Figure 13)

D. Scilab

Further exploration of the data was done using Scilab. Figure 10 shows how the data is visualized in 3 graphs for data values X, Y and Z.

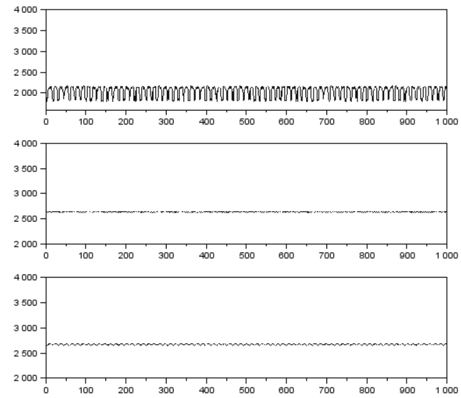


FIGURE 10. ECO NODE SENSOR DATA PLOTTED IN SCILAB

E. Example cases: Falling Body

A sensor node is mounted on a human body (Figure 11). The sensor node sends its data to the host. When the test person fell we obtained the corresponding dataset. As a reference setup, a wooden stick was used instead of a human body. The sensor node was mounted on top and a hinge was mounted at the bottom. By hand we gave a small push on top of the stick to get it moving and let it fall by gravitational forces.

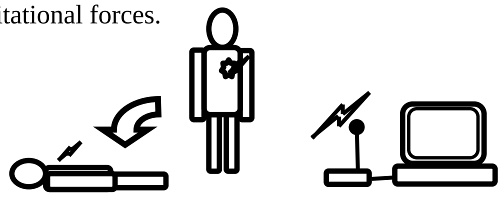


FIGURE 11. FALLING BODY

Figure 12. is the typical data representation of a fall. (starting position is X direction with switch up; end position is Z direction with LED Up).

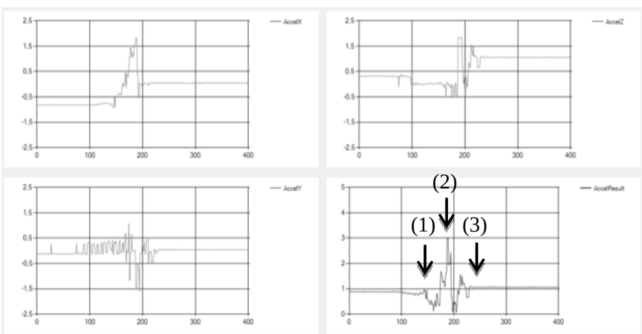


FIG. 12. FALLING STICK

When a fall happens, first the acceleration resultant value drops a bit (1), then it rises quickly (2). At the end when the stick stops moving we noted that the acceleration resultant value became steady (3) (Figure 12).

Figure 13 is the representation of a walking person. (X direction switch down). When the person was walking we did not detect the characteristic pattern like at fall detection.

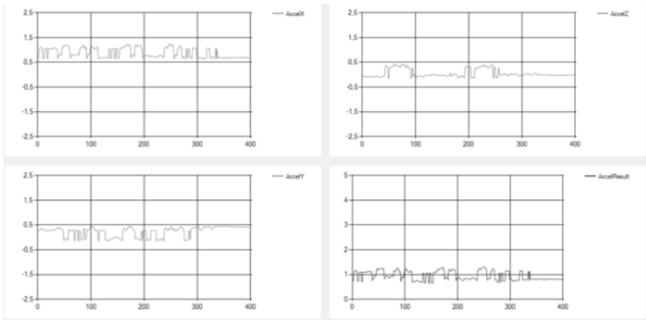


FIGURE 13. WALKING PERSON

IV. FUTURE WORK

The development of an accurate fall detection algorithm requires an extensive and well annotated database containing signals of measured fall incidents. Future work will consist of using this described wireless sensor network to build such a database.

Battery lifetime is a major drawback in sensor nodes. In order to reduce wireless communication, an algorithm for the detection of fall incidents should be implemented on the sensor node using the programmable logic, rather than collecting data on a computer and performing the calculations offline.

Furthermore, alternative methods, such as power harvesting or a higher quality battery, to supply the sensor node from power, should be investigated.

V. CONCLUSIONS

The ultra-small sensor nodes have the advantage that they take little place. It was an advantage that we could work with several sensor nodes. Unfortunately we saw a lot of signal interruptions when the sensor node got covered for instance by a hand or an arm.

The sensor node evaluation kit came with a lot of software source code, which allowed a fast setup of the experiments.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Hausdorff JM, Rios DA, Edelber HK. Gait variability and fall risk in community–living older adults: a 1–year prospective study. Archives of Physical Medicine and Rehabilitation 2001;82(8):1050–6.

[2] Lord S.R., Sherrington C.,Menz H.B., "Falls in older people: riskfactors and strategies for prevention", Cambridge: Cambridge University 2001

[3]http://epl.cs.nthu.edu.tw/EcoKit/download/ECO_tutorial_v1.0.pdf

[4] http://luci.ics.uci.edu/websiteContent/weAreLuci/biographies/faculty/djp3/LocalCopy/1612921.pdf

[5] Autocalibration of MEMS Accelerometer, Frosio I. and Borghese A., IEEE Transactions on Instrumention and Measurement, Vol. 58, No. 6, June 2009